COLLECTING WATER-QUALITY AND QUALITY-CONTROL SAMPLES

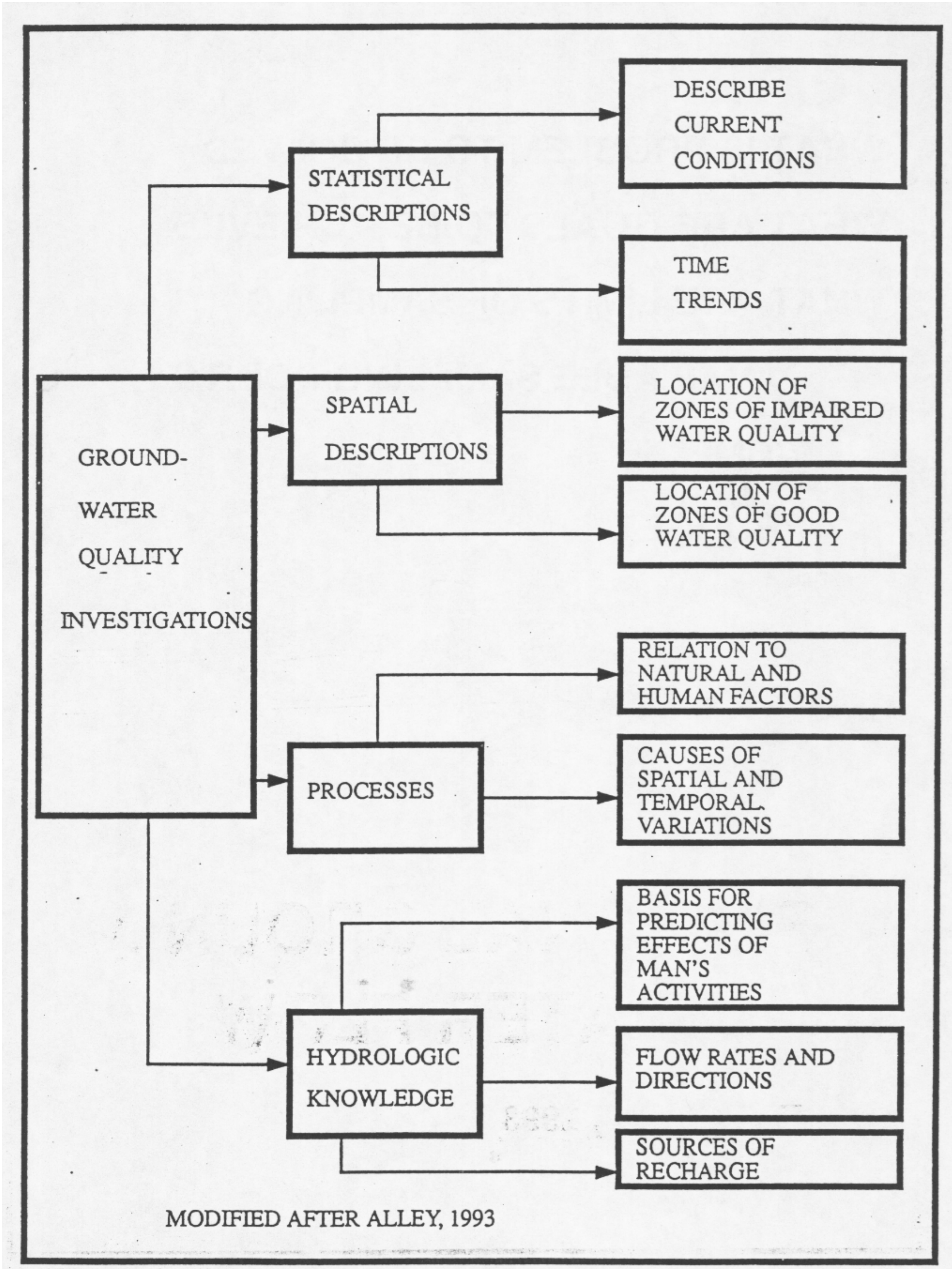


Table – Purposes of ground-water-quality investigations

RELATE SAMPLING TO STUDY GOALS

- What is the problem to be solved
- What are the goals to be achieved
- What are the limits of sampling
    - Available sampling points
    - Time
    - Budget

OPTIMIZE FOLLOWING RESTRAINTS

- Greatest understanding of system
- Best address of study goals
- Collect representative samples
- Select meaningful parameters
- Integrate study-specific QA/QC
- Select relevant and applicable sampling and analytical methods

SAMPLING STRATEGY

- What type of study?
    - Site Specific
    - Regional
- When are samples collected?
    - Synoptic
    - Temporal trends
-

Where are samples collected?
    Vertical
    Horizontal
        Upgradient/background
        Down/cross-gradient
        (consider DNAPL's)

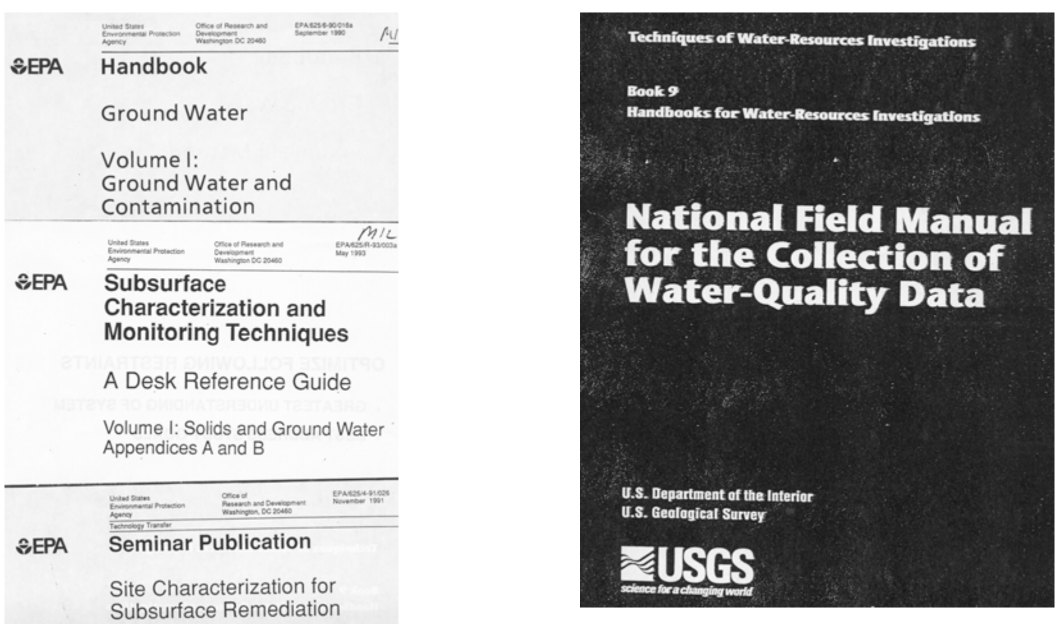


Figure--Examples of ground-water-quality sampling methodology manuals

KEY CONCEPTS

- Representative sample: reproducible and unbiased sample within defined limits of variability
- Every step requires thinking: data collection is never “canned”

OUR ENEMIES

- TIME – Reactions can be rapid-temperature can affect reaction rate
- PRESSURE DECREASE – Pressures can be much greater than atmospheric in ground water (organics may volatilize with change in pressure due to atmospheric affects and sampling procedure; loss of inorganic gases)
- EXPOSURE TO ATMOSPHERE – Introduction of atmospheric gases and dust; Evaporation (introduced oxygen may result in oxidation and precipitation of Fe and Mg, co-precipitation of As, Cu, Mo, U, etc.; VOC’s may be introduced by storage of chemicals in pump house or field vehicle, exhaust fumes)
- MIXING WITH NON-AQUIFER LIQUIDS – Due to well construction and development (multi-well systems; water-treatment systems)
- LEACHING AND ABSORPTION – From equipment , well materials, storage/ pressure tanks

DESIGN ACTIVITIES TO MINIMIZE THE EFFECTS OF “ENEMIES”

- RULES FOR GOOD FIELD PRACTICE
  - Know the “enemies”
  - Wear gloves and other protective equipment
  - Use cleaned equipment
  - Minimize sample-handling steps
  - Collect field blanks
  - Plan sight visits so that you sample from lowest to highest concentrations of target constituents
    - Upgradient to downgradient
    - Lowest ionic strength to highest strength
    - Pristine to contaminated

ADDITIONAL GFP'S FOR COMBATTING "ENEMIES"

- TIME – Minimize temperature increases and time for reactions (minimize sample handling time)
- LOSS OF PRESSURE – Use equipment that minimizes pressure decreases (use in-line filtration, positive displacement pumps)
- EXPOSURE TO ATMOSPHERE – Use enclosed systems (use flow-through cells; in-line filtration; collection and preservation chambers; flush filters; bottom fill bottles)
- MIXING WITH NON-AQUIFER LIQUIDS – Isolate the sample aquifer (flush sampling equipment; develop well)
- LEACHING AND ADSORPTION – Select correct materials; minimize flow rate; Minimize surface contact

USE A PREFIELD ACTIVITIES CHECKLIST

Table. – Prefield activities checklist

Order and make a checklist of supplies and equipment
Clear site access (permits, owner notification, etc.)
Create and maintain a site file for each well (for field as well as office reference)
Create schedules of planned field activities, including laboratory schedules of analytes
Prepare field sheets: complete site-descriptive information on field forms and National Water Quality Laboratory analytical services request forms (except for date, time, sample data)
Ascertain proper storage of supplies and equipment (to avoid equipment contamination and preserve chemical integrity of reagents)
Prepare supply of District-deionized water (routinely analyzed for targeted analytes)
Routine equipment maintenance and operation checks
Charge batteries
Preclean new/used equipment
Collect prefield equipment blanks
Wash, cap, label, and bag sample bottles
Arrange proper storage and disposal of hazardous materials
Update computer files; run quality-assurance checks on data

Table – Information to obtain when sampling water-quality data-collection activities

1. **Type of Well Hookup for Sampling:** Determine if a hookup to a garden-hose-threaded flow valve (common for water-supply wells) or to a portable, submersible pump (common for monitoring wells) is needed for sample collection.

2. **Depth Measurements**: Measure the depth of the well and depth to the water level in the well to check well-construction integrity and to determine pump lift, height of water column, volume of standing water held in the well, and purge volume.[1]

3. **Site Conditions and Restrictions:** Note road or access conditions to the well, areas of low clearance, limits on arrival and departure times, or presence of roaming animals (for example, livestock or pets) that could create problems for a field team.

4. **Contact Person**: Obtain land- or well-owner name and telephone numbers (business and home) and contact owner before or upon arrival, and perhaps upon departure.

5. **Local Maps and Photographs**: Locate well on maps, site sketches, or photographs, and indicate the measuring point for well-depth measurements, as well as areas for equipment setup and waste discharge.

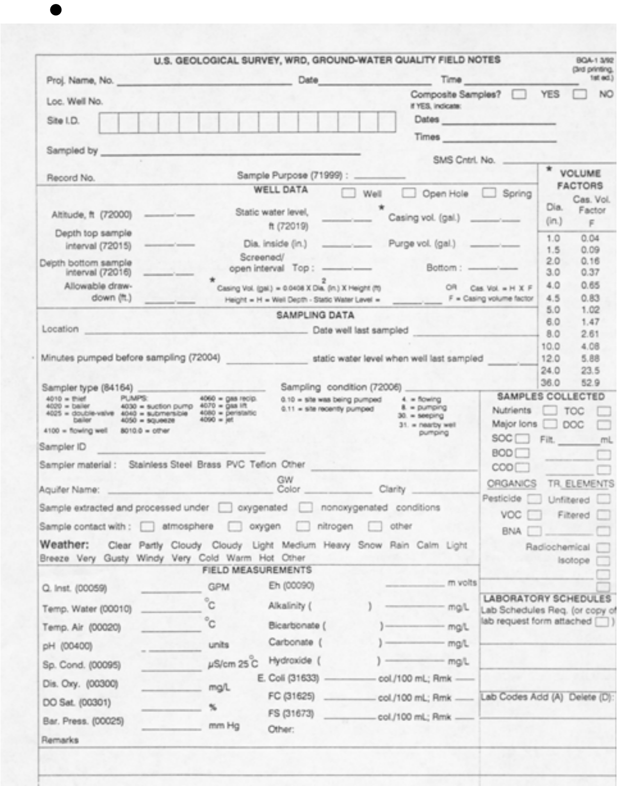
6. **Travel Maps and Travel Times**: Identify route and travel times from District office or previous site, and possible tunnel or bridge restrictions on the transport of gasoline, bottled gas, or methanol (or other organic cleaning agent).

---

[1]Measurements are made in accordance with National Water-Quality Assessment Program and U.S. Geological Survey protocols (Lapham and others, in press). Purge volume is defined as three times the volume of standing water in the well casing or, in absence of a casing, the borehole.

Figure. – Example of U.S. Geological Survey field record

-



U.S. GEOLOGICAL SURVEY, WRD, GROUND-WATER QUALITY FIELD NOTES

BQA-1 3/92 (3rd printing, 1st ed.)

Proj. Name, No. ______ Date ______ Time ______

Loc. Well No. Composite Samples? ☐ YES ☐ NO

If YES, indicate: Dates ______ Times ______

Site I.D.

Sampled by ______

SMS Cntrl. No. ______

Record No. Sample Purpose (71999) : ______

WELL DATA ☐ Well ☐ Open Hole ☐ Spring

Altitude, ft (72000) ______ Static water level, ft (72019) ______ * Casing vol. (gal.) ______

Depth top sample interval (72015) ______ Dia. inside (in.) ______ Purge vol. (gal.) ______

Depth bottom sample interval (72016) ______ Screened/open interval Top : ______ Bottom : ______

Allowable draw-down (ft.) ______

* Casing Vol. (gal.) = 0.0408 X Dia.^{2} (in.) X Height (ft) OR Cas. Vol. = H X F

Height = H = Well Depth - Static Water Level = ______ F = Casing volume factor

* VOLUME FACTORS	
Dia. (in.)	Cas. Vol. Factor F
1.0	0.04
1.5	0.09
2.0	0.16
3.0	0.37
4.0	0.65
4.5	0.83
5.0	1.02
6.0	1.47
8.0	2.61
10.0	4.08
12.0	5.88
24.0	23.5
36.0	52.9

SAMPLING DATA

Location ______ Date well last sampled ______

Minutes pumped before sampling (72004) ______ static water level when well last sampled ______

Sampler type (84164) ______ Sampling condition (72006) ______

4010 = thief; 4020 = bailer; 4025 = double-valve bailer; 4100 = flowing well; PUMPS: 4030 = suction pump; 4040 = submersible; 4050 = squeeze; 8010.0 = other; 4060 = gas recip.; 4070 = gas lift; 4080 = peristaltic; 4090 = jet

0.10 = site was being pumped; 0.11 = site recently pumped; 4. = flowing; 8. = pumping; 30. = seeping; 31. = nearby well pumping

Sampler ID ______

Sampler material : Stainless Steel Brass PVC Teflon Other ______

Aquifer Name: ______ GW Color ______ Clarity ______

Sample extracted and processed under ☐ oxygenated ☐ nonoxygenated conditions

Sample contact with : ☐ atmosphere ☐ oxygen ☐ nitrogen ☐ other

Weather: Clear Partly Cloudy Cloudy Light Medium Heavy Snow Rain Calm Light Breeze Very Gusty Windy Very Cold Warm Hot Other

SAMPLES COLLECTED

Nutrients ☐ TOC ☐

Major Ions ☐ DOC ☐

SOC ☐ Filt. ______ mL

BOD ☐

COD ☐

ORGANICS TR. ELEMENTS

Pesticide ☐ Unfiltered ☐

VOC ☐ Filtered ☐

BNA ☐

Radiochemical ☐

Isotope ☐

FIELD MEASUREMENTS

Q. Inst. (00059) ______ GPM Eh (00090) ______ m volts

Temp. Water (00010) ______ °C Alkalinity ( ) ______ mg/L

Temp. Air (00020) ______ °C Bicarbonate ( ) ______ mg/L

pH (00400) ______ units Carbonate ( ) ______ mg/L

Sp. Cond. (00095) ______ µS/cm 25°C Hydroxide ( ) ______ mg/L

Dis. Oxy. (00300) ______ mg/L E. Coli (31633) ______ col./100 mL; Rmk ____

DO Sat. (00301) ______ % FC (31625) ______ col./100 mL; Rmk ____

Bar. Press. (00025) ______ mm Hg FS (31673) ______ col./100 mL; Rmk ____

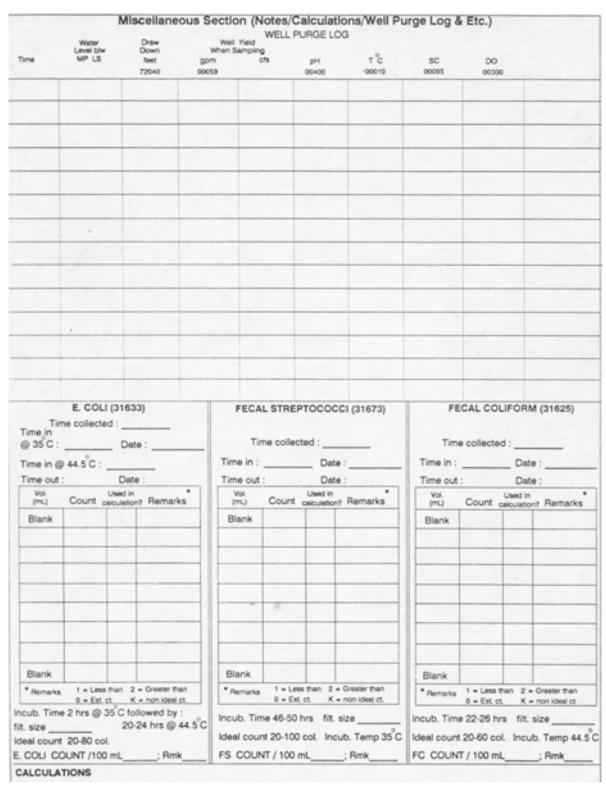
Other:

Remarks

LABORATORY SCHEDULES

Lab Schedules Req. (or copy of lab request form attached ☐)

Lab Codes Add (A) Delete (D):



Miscellaneous Section (Notes/Calculations/Well Purge Log & Etc.)

WELL PURGE LOG

Time	Water Level b/w MP LS	Draw Down feet 72040	Well Yield When Sampling gpm 00059	cfs	pH 00400	T °C 00010	SC 00095	DO 00300	

E. COLI (31633)

Time collected : ______

Time in @ 35°C : ______ Date : ______

Time in @ 44.5°C : ______

Time out : Date :

Vol. (mL)	Count	Used in calculation?	Remarks *
Blank			
Blank			

* Remarks 1 = Less than 2 = Greater than 0 = Est. ct. K = non ideal ct.

Incub. Time 2 hrs @ 35°C followed by : 20-24 hrs @ 44.5°C

filt. size ______

Ideal count 20-80 col.

E. COLI COUNT /100 mL______; Rmk____

FECAL STREPTOCOCCI (31673)

Time collected : ______

Time in : ______ Date : ______

Time out : Date :

Vol. (mL)	Count	Used in calculation?	Remarks *
Blank			
Blank			

* Remarks 1 = Less than 2 = Greater than 0 = Est. ct. K = non ideal ct.

Incub. Time 46-50 hrs filt. size ______

Ideal count 20-100 col. Incub. Temp 35°C

FS COUNT / 100 mL______; Rmk______

FECAL COLIFORM (31625)

Time collected : ______

Time in : ______ Date : ______

Time out : Date :

Vol. (mL)	Count	Used in calculation?	Remarks *
Blank			
Blank			

* Remarks 1 = Less than 2 = Greater than 0 = Est. ct. K = non ideal ct.

Incub. Time 22-26 hrs filt. size ______

Ideal count 20-60 col. Incub. Temp 44.5°C

FC COUNT / 100 mL______; Rmk______

CALCULATIONS

FIELD SEQUENCE GROUND-WATER SAMPLING

1. **Decontaminate equipment used in well sampling**
2. Determine purge volumes from measured water level in well
3. Purge well (Volume and Stability of Field Water-Quality Characteristics)
4. Collect field measurements of water quality – **Use a flow-through cell**
5. Collect sample
6. Preserve samples
7. Decontaminate equipment used in well sampling

Prior to sampling a well, the sampling equipment must be precleaned (decontaminated) and standing water in the well casing or well bore must be removed to ensure the sample is representative of aquifer water quality.

DECONTAMINATION

- PURPOSE

- Reduces contamination of the subsurface from equipment used in the well
- Reduces possible cross contamination between wells
- Ensures the sample chemistry represents the aquifer chemistry at the sampled location

WHAT SHOULD BE CLEANED

- Measuring tapes, pumps/other sampling equipment, bottles; mobile lab
- Similar considerations for other aspects of ground-water study (drilling, and lithologic Sampling equipment; well completion, construction and well-development equipment) (generally will include heated-water high-pressure wash)

HOW SHOULD EQUIPMENT BE CLEANED

- Procedure depends on degree and type of contamination, project objectives, and data quality objectives
- At a minimum:
  - Scrub/wash/circulate with non-phosphate detergent solution
    - Liquinox) (0.5-2%)
    - Trisodium phosphate (2-4 lbs/gallon)
    - Others for compound specific cleaning
    - Bleach (2 Tsp/gallon) for disinfecting measuring tapes use in supply wells
  - Rinse with clean tap water
  - Flush with deionized or distilled water
  - Clean before equipment dries
  - Where feasible wrap clean equipment for transport/storage
- Method will vary with inorganic/organic analytes
  - Inorganic- - After rinse detergent, wash with 5% HCL solution, rinse with DI water, methanol

PRE-SAMPLING WELL PURGING

- Measurement of well-water volume
- Selection of purge method and pump placement
- Removal of predetermined number of well-water volumes
-

PURGE VOLUME CALCULATION

1. Measure depth to water from reference point
2. Measure or provide well depth (from measuring point) from well log
3. Calculate length of water column (Depth to water – well depth)
4. Calculate casing volume , in gallons (Length of water column x well diameter)
5. Calculate purge volume (casing volume x 3-5)

EXAMPLE PURGE-VOLUME CALCULATION

1. Depth to water = 10 ft
2. Well depth = 20 ft
3. Water column = 10 ft
4. Casing volume = 10 ft x ,163 gallons/ft (for 2-inch diameter well) = 1.63 gallons
5. Purge volume = 1,63 gal x 3 = 4.9 gallons

PURGE METHODS AND STANDARD PROTOCOLS

- Lowering pump – continuous or two step
- Fixed position just above open interval
- Micro-purge
- Dedicated pump – water withdrawn just above or within sample interval
- Use on of these withdrawal methods in conjunction with well-water volume and field characteristic stability criteria

Standard protocols and recommended procedures for conducting and assessing well purging (adapted from Lapham and others, 1995)

1. Purge minimum volume of water equal to 3 times the casing (or wellbore) volume (flow rate 2-3 gal/min or less)

2. Reduce flow rate to 0.1-0.5 gal/min during later part of purge period (5-25 minutes). Lower flow rate will approximate sample collection rate.

3. During purging, monitor pH, temperature, specific conductance, dissolved oxygen (DO), Eh, particularly during final 15-25 minutes. Monitor turbidity (TU) near the end of purging, particularly if sampling for trace elements. Note and record water clarity,

4. The well is considered purged after at least 3 casing volumes have been removed and values of the monitored field parameters between 3-5 successive measurements separated by about 3-5 minute intervals *or* 3 successive ½ well volumes are within the allowable differences specified below:

Parameter	Allowable difference or value
Ph	+- 0.1 units (+-0.05 units if instrument capable of display
Temperature	+-0.2^{o}C
Specific conductance	+- 5%, for SC <- 100 us/cm +-3%, for SC > 100us/cm
DO	+- 0.3 mg/L
Eh	+-5%
TU	+-10% for TU < 100 NTU; ambient TU Is <5 NTU for most ground-water Systems; visible TU > 5 NTU (or check visually for water clarity)

- If measurements appear stable, either the last *or* median value of the last 5 measurements for each parameter (except pH, use last) is recorded; proceed with sampling
- If criteria for stability is not achieved, purging is continued until either measurements stabilize or equivalent of 5 or more wellbore volumes have been removed; note unstable parameters in field notes
- If measurements remain unstable, determine study objectives/sampling priority. If sample, note parameters that are not stable

OTHER PURGE CONSIDERATIONS

- Lack of stability may indicate problems with well design or purge set-up and method
- Generally, Eh will stabilize last, followed by DO.
- If feasible water level in well SHOULD NOT be drawn down below top of open interval. Water levels can be monitored by e-tape or transducer and data used with flow rate to compute specific discharge
- Flow rate should be measured: use a gallon jug, 5-gallon pickle bucket, etc.
- **Micro (low-flow) -purging** at flow rates that approximate 0.1 gal/min theoretically withdraw water along a single flow line and do not induce negligible drawdown in the well. Purge volumes are measured in tubing volumes and pumps are located in the open interval of the well.
- For **continuously pumped wells** flush lines and pressure tank (if present); record field measurements 5 times at regular intervals prior to sampling; 3-5 casing volumes not required
- For **low-yielding wells** empty the well once and wait for 90% recovery

WATER-QUALITY SAMPLING PROTOCOL

- Monitoring wells
    - Use a submersible sampling pump (portable or dedicated) or a bailer appropriate for environmental sampling. If possible **avoid** the use of **bailers**; if necessary **use with bottom-emptying device**.

    - Collect sample at a flow rate of about 0.1 to 0.5 gal/min. For volatile organic compounds (VOC's a rate < 0.5 is recommended. A flow rate of 0.1 gal/min is not feasible for many pumps. Use a flow rate of about 0.1 gal/min for low-flow sampling. **Constant rate, non-turbulent flow for all samples.**

    - Store bottles at the ambient temperature or less of ground water (about 55^{o} F)

    - Use laboratory, quality-assured and cleaned bottles that are securely capped

    - Select proper bottle type for sample (polyethylene, baked glass, amber glass, etc.). Sample bottles for inorganic compounds are rinsed with sample water (unfiltered or filtered, as required) immediately before sample collection; Do not rinse glass bottles for organics.

    - If concerned with atmosphere, bottle can be filled to overflowing from bottom, otherwise fill to shoulder. Fill at non

    - Samples for volatile organics should contain **NO AIR**. Check for air. If present discard or empty bottle and recollect sample.

    - If necessary, filter sample with in-line filter. Invert and pre-flush filter with sample water; rinse with DI water. Generally use 0.45 um filter. Project objectives dictate pore size and type of filter. Report as **FILTERED, not DISSOLVED.**

        - Filtering may be done to: provide comparability with historical record; compatibility with other sources of data; removal of well-installation and samples withdrawal artifacts (increases reproducibility); remove source of bias (suspended carbonate may interfere with alkalinity measurements); project objectives (geochemical modeling). Often samples collected by regulatory agencies are NOT FILTERED in order to provide an indication of the drinking-water quality at point of distribution.

        - Collect the filtered anion and alkalinity sample sequentially

    - Preserve samples, as necessary (acidification, chilling to < 4^{o} C). Different protocols require acidification before or after sample collection.

        - Preservatives maintain the integrity of the sample (retard biologic degradation of VOC's; keep metals in solution)

    - After decontamination of sampling equipment, periodically (about 1 per 20 samples, including before the start of sampling, following sampling of a highly contaminated well, and from each type of pump used). Use the standard decontamination procedure to collect the field blank.

- Water-supply wells

    - Reduce flow rate to 0.5 gal/min or less. Select a sample location before water treatment equipment and pressure tanks. Avoid use of threaded and dirty/rusty taps. Pre-clean tap with non-phosphate detergent and rinse before sampling, if necessary.

SAMPLING EQUIPMENT

Ground-water-sampling pumps used in water-quality studies require several essential characteristics:

- Submersible, positive displacement: gear or worm drive
- Constructed of inert materials: stainless steel and Teflon
- Low flow rate (<1 gal/min), preferably variable between 0.1 and about 2 gal/min

Other sampling devices may include bailers (Teflon) and peristaltic pumps, which. If possible avoid use of these devices, particularly when sampling VOC's. Bailers agitate samples and expose them excessively to the atmosphere. Peristaltic pumps rely on suction (negative pressure) to extract water samples. In some cases, these devices must be used – **bailers** where water levels in wells are too low to withdraw sample with a submersible pump, water in well is very turbid or highly contaminated, particularly with hydrocarbons that may foul pump**; peristaltic pumps** where well diameter is too small for submersible pump (although pump is limited sampling where depths to water are less than about 29 ft.).

SAMPLER PERFORMANCE – ORGANIC SAMPLES
EFFECIENCY OF SAMPLERS TO PROVIDE RECOVERY OF COMPOUNDS AT 20, 100 UG/L

- RECOVERY > 95%
  Grunfos Redi-Flo2
  Fultz SP-300
  Bladder pumps
  Bennett Pump
  Keck SP-81

- RECOVERY < 95%
  Teflon bailer (top emptying as low as 85%)

SAMPLER PERFORMANCE – INORGANIC SAMPLES
SAMPLERS PROCESS DI WATER WITHOUT CONTRIBUTING INORGANIC CONSTITUENTS AT CONCENTRATIONS OF 1.0 UG/L

RECOVERY >95%
  Grunfos Redi-Flo2
  Fultz SP-300
  Bladder pumps
  Bennett Pump
  Teflon bailers

- RECOVERY < 95%
  Teflon bailer (top emptying as low as 85%)

- Various types of pumps are used in large diameter water-supply wells (> 4 inch diameter). In most cases, turbine pumps will be found in high-capacity industrial and public-supply wells and submersible positive displacement pumps will be found in low-capacity (about 5-30 gal/min) domestic wells. If possible, avoid wells with jet pump when selecting wells for sampling.
- Submersible pump
- Piston pump
- Centrifugal pump
- Jet pump

PUMP SELECTION CRITERIA

- Materials -- Consider “Enemies” (select pump with inert materials: SS, Teflon)
- Water withdrawal mechanism – Consider “Enemies” (select positive displacement)
- Flow rate – Consider “Enemies” (low flow: 0.1 – 2 gal/min); variable rate best
- Cost - $2500-$5000 (bailers about $200)
- Portability
- Power source (portable battery pack, 12V car battery, 115-VAC, 220-VAC compressed air) Variable source preferred

;

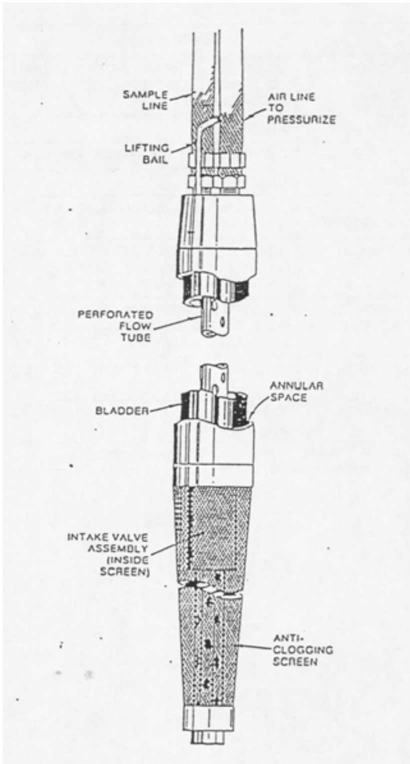


Figure.—Schematic of bladder pump (typically dedicated to well)

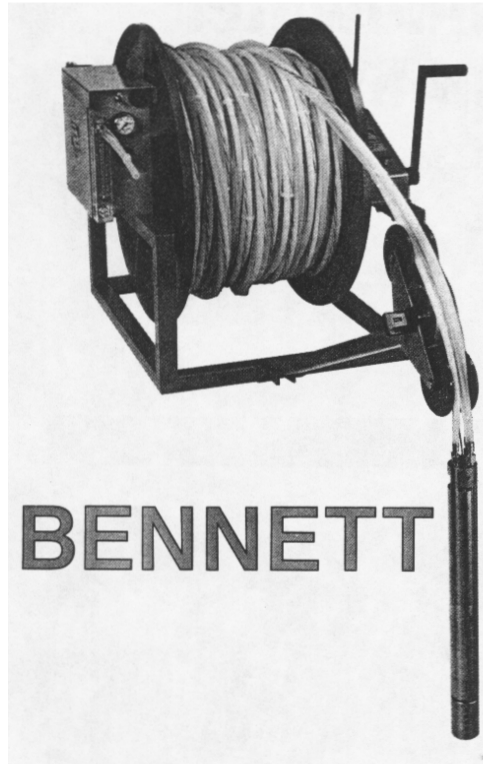


Figure. – Submersible piston pump

SAFETY CONSIDERATIONS

- Wear protective clothing (PPE) if sampling potentially hazardous ground water
  - Level A-D
  - Select proper glove for contaminant sampled for (natural rubber, neoprene, PVC, nitrile)

- Monitor air quality at well head with organic vapor or gas-specific analyzer, if sampling in potentially hazardous setting (photoionization/flame ionization, cyanide detectors)

- Consider medical monitoring, immunizations, if appropriate

- Prepare site-hazards analyses/safety plan with information of nearest hospital

QUALITY-ASSURANCE/QUALITY-CONTROL ISSUES

QUALITY CONTROL ALONG WITH QUALITY ASSURANCE AND DATA VALIDATION ARE PARTS OF A FORMALLY ESTABLISHED PROCESS INTENDED TO ENSURE DATA COLLECTED FOR PROJECTS ARE:

1) Of such a quality that they are useful to address project goals

2) All information regarding data quality are documented and defensible

- Data “quality” refers to the magnitude of error associated with a data set and uncertainty relative to end-use requirements and is expressed in terms of precision, accuracy, and representativeness

- Quality assurance involves a management QA plan and auditing results as the project evolves

QUALITY ASSURANCE BEGINS AT THE START OF THE PROJECT!

BASIC QUALITY ASSURANCE PRINCIPLES

- All activities are controlled by project objectives (USGS SOP’s provide methods for meeting most project objectives)

- Field protocols are designed to ensure that project objectives are met

- Quality assurance allows us to document that we have met project objectives

PROJECT OBJECTIVES CONTROL:

- Strategy for Quality Control – types, distribution, and frequency of QC samples and analytical methods

- Field Strategy – where, when, and what to sample

- Methods and Equipment – wells, pumps, filtration, measurements, preservation

- Documentation – have we met project objectives

COMPLETING SUPPORTING DOCUMENTATION

Ground-water studies require careful and complete documentation of site information and criteria and methods used for the selection and installation of wells, and collection of geologic, geophysical, hydraulic, and water-quality data and samples. Such documentation is integrated throughout each process.

Systematic documentation is:

- a basic component of quality assurance—provides the basis for evaluating the utility of data for a specific objective
- aids in interpretation of data
- provides a historical reference for future use of the data or sampling location (well)

For example, documentation of a well site involves the establishment of a file that includes paper and electronic records that describes the field verified location with map and photographs of site; available construction information (commercial driller's permit on file w/ State or contracted driller's log. Commercial log may contain information on the geologic units and thicknesses, water level, well materials and position, specific-discharge tests, installed pumps), geophysical logs; water-level and water-quality data; land-use information; and permission agreements

USGS establishes an electronic well record in the National Water Information System (NWIS) data base. Other government agencies (ISGS, IEPA) maintain their own data bases.

USEFUL REFERENCES:

Wood, W.W., 1981, Guidelines for collection and field analysis of ground-water samples for selected unstable constituents: U.S. Geological Survey Techniques of Water-Resources Investigations of the United States Geological Survey, Book 1, Chapter D2, 24 p.